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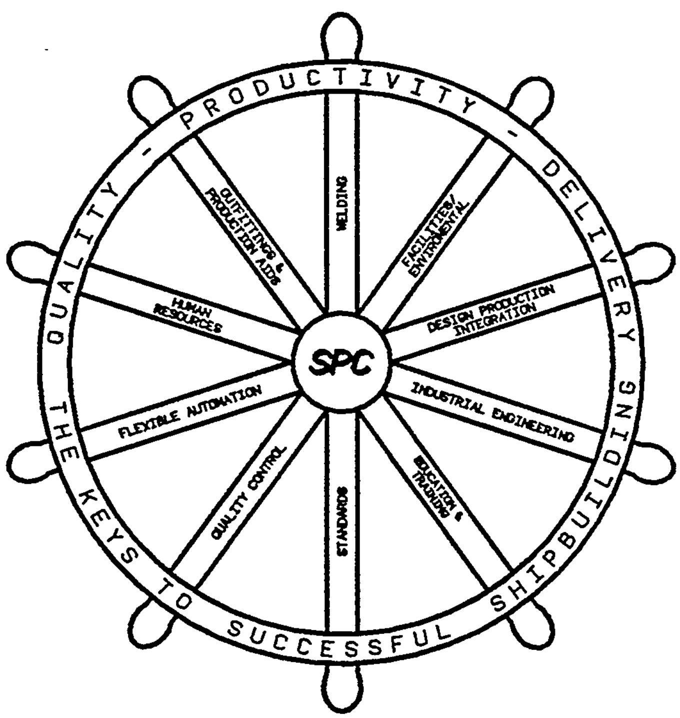

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Commonality-Based Naval Ship Design, Production & Support

CDR Michael L. Cecere III, USN (V)-Advanced Surface Machinery Programs Office, NAVSEA SEA03Z
Jack Abbott (LM)-ATC Project, NKF Engineering, VA.
CDR Michael L. Bosworth, USN (LM)-ATC Project, NAVSEA, SEA03R3, VA.
Tracy Joseph Valsi (V)-ATC Project, Gibbs & Cox, Inc., VA.

ABSTRACT

The Naval Sea Systems Command (NAVSEA) began an initiative titled “Affordability Through Commonality” (ATC) in 1992. The effort’s long-term goal is to improve the process by which the Navy, with industry’s help, will design, acquire, and provide lifetime support for the ships required for national defense. The technical approach considers commonality to be a synergistic combination of the elements of modularity, increased equipment standardization, and process simplification. A division within NAVSEA (SEA 03R3) was created to coordinate efforts towards this fleet affordability goal, specifically to:

- identify and develop analysis tools for a commonality based process,
- assemble resources for initiating a decade-long task,
- develop a plan for a commonality-based approach to ship design, acquisition, and lifetime support and
- implement the plan into the mainstream of the Navy’s way ofconducting business.

This paper provides an interim report on the ATC project’s first funded year and the implementation progress of the first program to fully adopt commonality principles, the Advanced Surface Machinery Programs (ASMP), SEA 03Z.

INTRODUCTION

Rear Admiral Millard Firebaugh and Captain Robert Percival presented the ATC concept before the Ship Production Symposium last year (l). The ATC project office was established within the Naval Sea Systems Command in August 1992 with a charter to develop the necessary strategies, standards, designs, specifications, and procedures to provide the Navy the means to lower the costs of fleet ownership through the use of increased commonality. Commonality is defined as the synergistic combination of the three pillars of

- equipment modularization,
- increased equipment standardization, and
- process simplification.

The use of increased commonality in naval ship design and acquisition can lead to shorter design and construction times, maintain economical procurement quantities in the face of a reduced fleet construction schedule, improve shipbuilding quality control, and facilitate ship operation, maintenance, and upgrade. The goal of the ATC project is to build upon previous programs which fostered modularization, standardization and process simplification, and to work in conjunction with other current initiatives which support the goals of fleet affordability.

BACKGROUND

The ATC initiative was formulated in response to three issues that have emerged, or have become more prominent over the past several years with the decline of the Soviet military threat and the increase in global economic competitiveness. First, there is an affordability crisis that has been building for years, evidenced by rising naval ship costs. With the end of the Cold War, the defense budget is under steady downward pressure, and is likely to continue decreasing for some years. The decrease in the size of the fleet has significantly reduced the number of naval ship orders, causing corresponding unit-cost increases due to loss of production volume.

The second problem is the shrinking U.S. maritime

industrial base. There has been a historic problem with maintaining U.S. commercial shipbuilding competitiveness, with occasional periods of great activity and world leadership (notably World War II). Most recently, however, United States shipbuilding activity for large commercial ships has become nearly non-existent. The naval expansion of the 1980s obscured this trend to some extent with increased naval ship orders. With the current decrease in naval shipbuilding however, the number of competitive shipbuilders and supporting vendors is decreasing at an alarming rate.

The third issue that prompts consideration of commonality is the increased uncertainty in the national strategic situation. After decades of a relatively predictable threat, there is now considerable discussion in defining the maritime threat, how our defense should be configured to counter the threat, and what other threats might develop in the future. The uncertainty in this area increases the need for and value of flexibility in the design and operation of U.S. weapons platforms (2, 3).

Commonality Concept Description

ATC'S goal is to reduce the cost of ship acquisition and in-service support by reducing the cost and complexity of ship design, procurement, production, fleet introduction, and life cycle operations and support. This objective will be achieved through the use of equipment modularization, increased equipment standardization, and process simplification.

Equipment modularization is the determination of packaging and interface standards at the system level. This entails the joining of components into larger subassemblies in a way that enhances production efilciency, provides flexibility for in-service maintenance and upgrade efforts, and enables increased equipment standardization by grouping these components into reusable design elements. Ultimately, these modules are intended to be utilized across ship classes.

Increased equipment standardization is the reduction of the number of piece parts necessary to support the Navy. Standards, specifications, and design criteria will be developed for each family of common modules; the policy of increased standardization will be implemented in the development of these modules. The challenge will be to determine what unique requirements to impose and how much standardization to maintain in these module designs.

Process simplification includes the strategies, policies, and procedures to implement the following:

- Fewer, more standard system designs (Hull, Mechanical &Electrical [HM&E] initially, other systems as resources permit),
- Selective implementation of military specifications and standards,
- Procurement of equipment at the fleet level,
- Generic and engineered build strategies for each type of ship,
- Improved and efficient assembly of major equipment and systems,
- Increased parallel assembly and test of equipment and systems during ship construction,
- Fewer systems and less equipment to support (i.e., spares, training, etc.),
- Standardized, replaceable components and subassemblies to facilitate maintenance and modemization, and
- Use and reuse of digital data across discipline lines and across the boundaries of design, acquisition, production, and in-service engineering.

Thus, the processes to be simplified include ship design, production, logistics suppo~ and requirements definition. This simplification will depend upon the degree to which the concepts of modularity and standardization are adopted in the form of common equipment modules built to ATC standards, i.e., standard components packaged as larger subassemblies for installation and service in various classes of ships (Figure 1).

The output of ATC will be development of designs, standards, and procedures which reflect an architecture of "commonality" across the fleet at the sub-system level. The approach is to identify cost-drivers, determine the extent to which common modules and improved procurement practices can reduce the time and cost of the ship acquisition process, and create a plan of action for the development of appropriate sub-system designs, standards, and procedures. Criteria will be developed for determining the degree of standardization and modularization required for each major sub-system. Industry will play a major role in developing this plan of action.

Overview of ATC/ASMP FY93 Tasks

In the fiist developmental year (1993) of this multi-year process improvement task, both top-down systems engineering and detailed prototype engineering were initiated. Coordination and cooperation with the ASMP program office also continued from ATC'S 1992 study phase. Management of the ATC efforts was divided into the following categories:

- Design integration management,

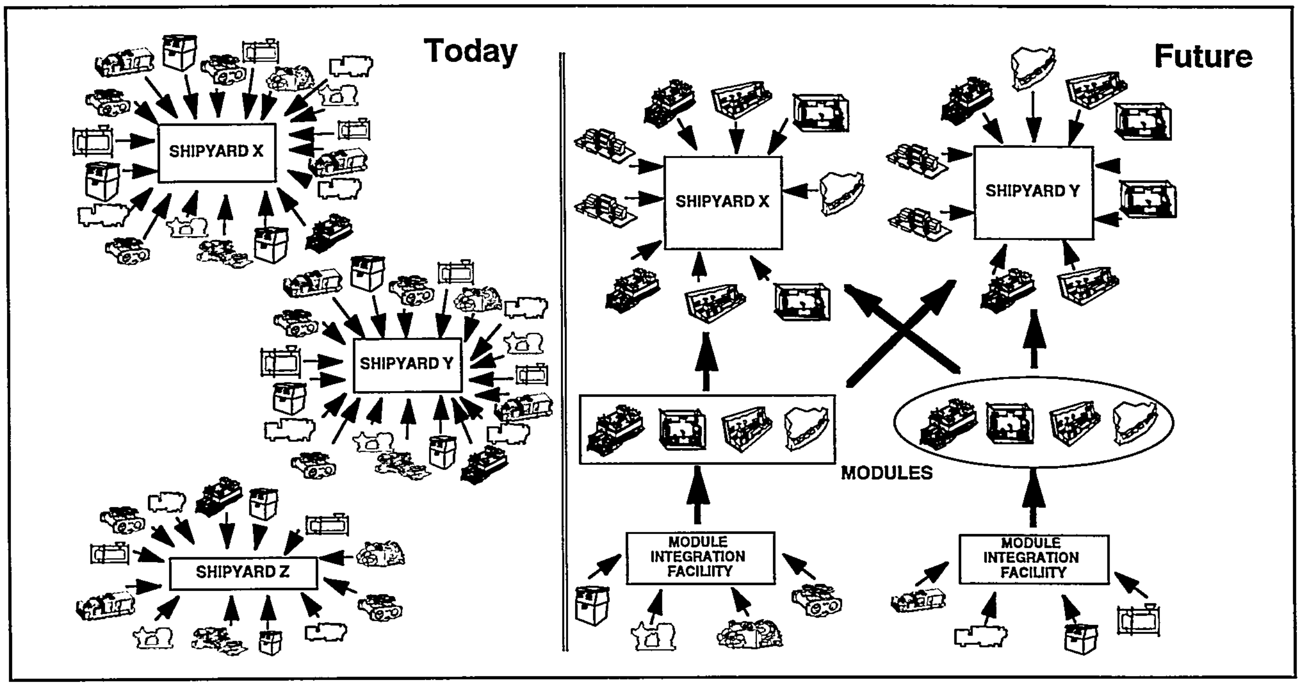


Figure 1. The Vision of Increased Commonality

- . Cost analysis and model development,
- . Plans and programs,
- . Integrated logistics support and special projects,
- . Hull and habitability systems,
- . Machinery systems,
- . Production processes,
- . Combat systems, and, to be added in the future,
- . Command, control, communications, computers and intelligence (C41).

Each task within these categories was prioritized for various levels of early funding. Each category has an Assistant Project Manager (APM) with intercategory coordination achieved through management team ofilce co-location and regular meetings of the full team. In addition to these efforts, the ASMP (whose representatives attend all ATC team meetings) administered the following tasks related closely to ATC goals:

Naval ship architectural studies characterize Integrated Power Systems (IPS) and identify associated machinery modules which support proposed combatant, amphibious and auxiliary ship concepts (Figure 2).

Commercial ship studies establish machinery system baselines for various commercial ship types in order to establish design-to-cost targets for comparable IPS systems and modules.

Costing tasks estimate costs to build, pre-test, and install machinery modules derived in naval ship architectural studies. It also includes the establishment and implementation of a formal life cycle cost model, which includes all costs associated with design, acquisition, construction, fleet introduction, and operating and support of IPS modules across the fleet (Figure 3).

IPS/pulse power integration studies characterize pulse power weapon support systems in terms of machinery modules.

The ASSET model update task updates the ASSET Ship Synthesis Model to allow rapid detailed evaluation of IPS modular machinery systems concepts for naval combatant and non-combatant ships.

There is a diverse range of disciplines and skills on the ATC/ASMP team, composed of government personnel (headquarters and laboratory), local support contractors, and geographically dispersed shipyards and suppliers. Some of the fiist year's efforts are reported to give a representative overview of the work being accomplished in the ramp-up year, work that will be continued and expanded upon in the out-years.

PRODUCT AND PROCESS IMPROVEMENT

Propulsion Systems

The IPS is **a** unified electrical power generation and management system serving all power requirements in naval surface combatant and non-combatant ships. Utilizing enabling technology advancements in permanent

Ship Type	Lead Award	No. in Class	Speed (kts)	Total SHP	No. of Shafts	Ship Service Load (KW)				Shock Rqmt	Data Source
						Shore	Anchor	Cruise	Mission		
SC-21	01	40?	28+	50,000	2	1800	2000	3650	3480	Yes	DDS Study 23 Apr 93
Amphib	96	12	23	40,000	2	4950	4950	5650	5850	Yes	LSD-41 LST-1179
Dry Cargo Shuttle	01	6	20	30,000	2	3275	4050	4450	5250	No	AFS-1 TAO-187
Repair	?	2	20	20,000	1	7650	8900	9500	21200	No	AD-41 AS-31
Sealift	00	40	24	60,000	2	2000	2050	3750	3650	No	SL-7

Figure 2. ASMP Target Ships

magnet materials and solid state power electronics, IPS consists of an architecture and a family of modules from which affordable, ship specific configurations can be developed for various applications. IPS incorporates use of Permanent Magnet (PM) Generators, PM Propulsion Motors and DC zonal electrical distribution, operating with the Standard Monitoring and Control System (SMCS).

To achieve cost savings without degrading performance, the ASMP concept incorporates the use of a selected group of common machinery modules across several ship classes, flexible power-sharing generation and distribution architectures, specification of standard hardware components, and maximum use of common software and control strategies.

The fundamental assumptions of the ASMP approach are

1. The correct choice of machinery system architecture can produce significant changes in the ship construction process, removing machinery systems installation from the critical path, and reducing ship constmction time and cost.
2. A small family of machinery modules can be developed from which a variety of affordable systems can be configured to serve many classes of ships. The resulting systems meet all performance goals. Design, acquisition, and life cycle costs for a limited set of modules composed of standard components and designed with standard interfaces for multiple ship configurations are less than the corresponding costs for multiple unique machinery systems.
3. Electricity will be the energy medium in naval ships of the future.
4. The SMCS will be the means for transmitting and distributing information within the ship. The SMCS will also provide standards for monitoring and control systems hardware (4).

The ASMP architecture is comprised of basic power system functions and their respective interface characteristics. A power system function is described as a sub-system entity whose purpose and interfaces can be well defined. For the IPS, the basic power system functions are:

. Power generation of electrical power for shipwide use,
. Power distribution throughout the ship,
. Power loads for conversion of electrical power into usable forms of energy for propulsion, auxiliary systems, lighting, etc.,
. Energy storage centers which alternately act as a power load or power source, according to system requirements, and
. Power system control of the IPS.

Proper definition of these functions, specification of interface standards, and identification of prospective applications are the keys to producing a family of machinery module designs from which a variety of affordable IPS configurations can be developed (Figure 4). This being

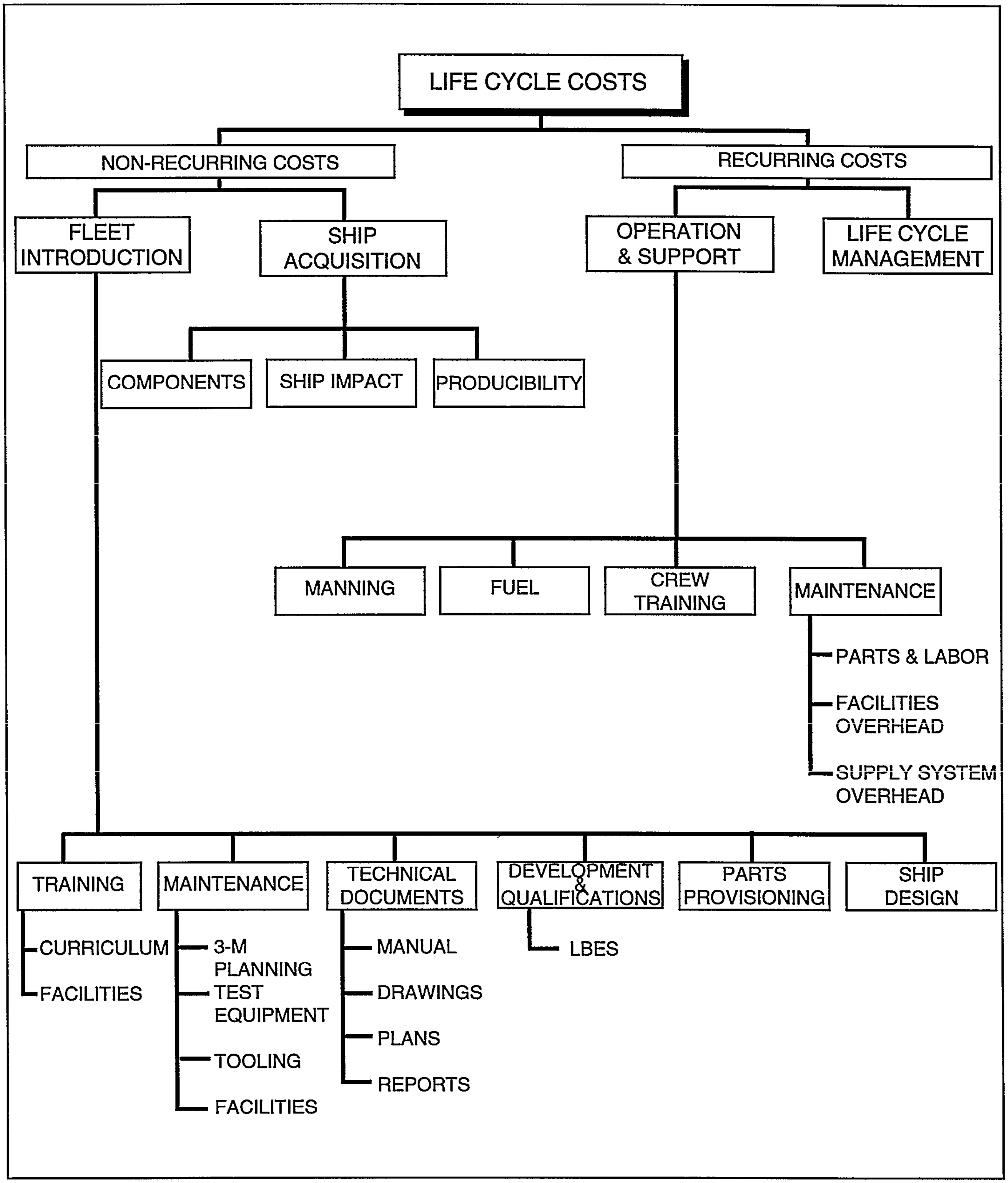


Figure 3. The ASMP Life Cycle Cost Model

done, ship machinery system design can be translated into a selection of the most economical combination of modules which satisfy machinery system performance requirements. A ship *configuration is* defined as the set of machinery modules (tailored as necessary) that meet specific ship performance requirements (Figure 5).

Thus, the design of a ship machinery system is essentially reduced to choosing the appropriate numbers and combinations of modules which meet ship requirements, using module characterization sheets to integrate these modules into the ship design. These characterization sheets provide Computer Aided Design (CAD) 3-D solid models and all other information required to incorporate these modules fully into the computer-aided ship design process (4) (Figure 6).

Electrical Systems

The Zonal Electrical Distribution System (ZEDS) represents a significant change in architecture from the conventional (radial) electrical distribution systems currently installed in naval ships. In conventional systems, electrical power is distributed by dedicated cables directly to user loads throughout the ship from a few centralized locations in the ship, namely the ship service switchboards and load centers. The result is thousands of cables running through all areas of the ship, crossing watertight boundaries and requiring significant portions of the ship for installation and protection. Phasing out of steam systems and proliferation of shipboard electrical and electronic equipment have contributed to an ever-increasing electrification of naval ships. At this point, the capabilities of radial systems have been pushed to the limit the electrical distribution system has become a significant factor in ship design and construction costs.

The ZEDS employs port and starboard longitudinal electrical busses to deliver power through the length of the ship. In each electrical zone, load centers tap electric power off the port and starboard busses, while distribution cables *located only in that zone* distribute power to user equipments in the zone. The principal components of the ZEDS are the port and starboard power busses, zonal load centers and associated switchgear (Figure 7). DC ZEDS assumes the availability of SMCS to provide monitoring and control services (5).

The ZEDS enhances ship producibility and affordability by reducing the amount of electrical cable required to be installed to support the ship's electrical distribution requirements, reducing the number of watertight bulkhead penetrations, and through the use of a solid sectional transmission bus enclosed in a protective duct as a planned replacement for conventional transmission cables (Figure 8). In addition, ZEDS allows the option of electrically connecting and powering all equipment in a given ship construction zone *before* it is joined to the rest of the ship, facilitating equipment test and checkout in a more accessible manner.

Auxiliary Systems

As a result of a strategic planning session held in November 1992, ATC is addressing the modularity of auxiliary machinery systems in two ways (6). From the large number of possible auxiliary machinery options considered, a Reverse Osmosis Desalinator Module (RODM) and a Zonal/Nlodular Heating, Ventilation and Air Conditioning (HVAC) system architecture were selected as the most promising candidates for development.

There are different reasons for the selection of these two tasks. Both are useful, fleetwide, and cost-reducing, yet their respective strengths and weaknesses are not the same, as shown in the tables below:

RODM STRENGTHS	ZONAL HVAC WEAKNESS
Backfit potential to fleet	**Requires ship architectural changes**
Low technical risk	**Difficult (new** thinking, research)
Attention getter	Obscure, esoteric
Good early building block	Long lead time (for results)

Table 1. Near-Term Benefits of the RODM

From the opposite view:

ZONAL HVAC STRENGTHS	RODM WEAKNESS

Table 2. Long-Term Benefits of Zonal HVAC

The reason for the selection of two candidates with such divergent attributes is that by exploiting the *benefits* of each, the auxiliaries team would use dramatically different cases to demonstrate the ATC approach to reducing ship cost. In one case, the team has taken the proven technol-

Power Generation Modules		**Status**
PGM 1	22 MW (29 KHP) ICR Generator Set	Under development
PGM 2	3.75 MW Diesel Generator Set	Concept design
PGM 3	3 MW Gas Turbine Generator Set	Existing

Propulsion Motor Modules		
PMM 1	20-25 KHP Single Rotation Motor	Under development
PMM 2	40-50 KHP Single Rotation Motor	Under development
PMM 3	50 KHP Contra Rotation Motor (Tandem 25 KHP Motors)	Concept design
PMM 4	Auxiliary Propulsion Motor	Existing

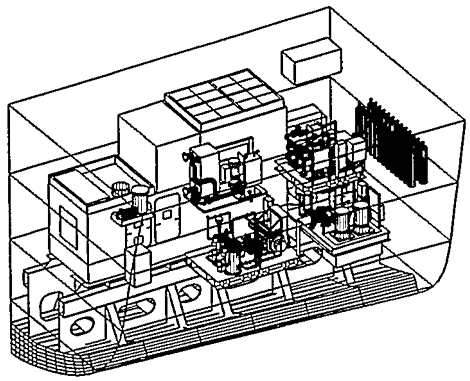
Electric Power Transmission/ Distribution/ Conversion Modules		
PDM 1	Propulsion Electrical Transmission System	Under development
PDM 2	**Zonal** DC Ship Service Distribution System	Under development
PDM 3	Zonal AC Ship Service Distribution System	Existing
PDM 4	Pulse Power Electrical Transmission System	Under development
PCM 1	Ship Service Power Conversion Module	Under development

Control Modules		
PCON 1	Supervisory Control Module	Under development

Figure 4. The Family of ASMP Modules

Ship	Power Gen	Prop. Motor	Elec Trans	Distribution	Control
SC-21	(2) PGM 1 (1) PGM 3	(2) PMM 1 (1) PMM 4	(1) PDM 1 (1) PDM 2 (1) PDM 4?	(7) PDM 3 (14) PCM 1	(1) PCON 1
Amphib	(2) PGM 1 (2) PGM 2	(2) PMM 1	(1) PDM 1 (1) PDM 2 (1) PDM 4?	(7) PDM 3 (14) PCM 1	(1) PCON 1
Dry Cargo	(1) PGM 1 (3) PGM 2	(2) PMM 1	(1) PDM 1 (1) PDM 2	(7) PDM 3 (14) PCM 1	(1) PCON 1
Repair	(1) PGM 1 (4) PGM 2	(1) PMM 1	(1) PDM 1 (1) PDM 2	(7) PDM 3 (14) PCM 1	(1) PCON 1
Sealift	(3) PGM 1 (1) PGM 2	(2) PMM 2	(1) PDM 1 (1) PDM 2	(7) PDM 3 (14) PCM 1	(1) PCON 1

Figure 5. ASMP Modules on Target Ships



Module Summary Characteristics

DESCRIPTION:	PGM —1 Generation Module with ICR Gas Turbine Engine — driven Generator, and propulsion support submodules and systems.

SWBS Group: VARIOUS		SUPPORT RQMTS:	
		FW:	NONE
RATING:	22 MW @ 750 VDC	LO:	NONE
		SW:	7200 1/MIN
		Air:	TBD
DIMENSIONS:		HVAC:	TBD
Length:	12.80 m	Electrical:	TBD
Width:	9.25 m		
Height:	10.00 m		
WEIGHT:	204,052 Kg. (Est.)	UNIT COST:	

Figure 6. ASMP Power Generation Module PGM-1

ogy of the Navy's new Reverse Osmosis Desalinator and integrated five individual pieces into a stand-alone module with fleetwide applicability. This modularization provides the ATC team with a usable, near-term product that allows the team to demonstrate and improve certain aspects of the modular process using a relatively simple system. At the same time, however, the ATC marine engineers have taken on the challenge of developing a Zonal/Modular HVAC architecture. This concept features strict vertical subdivision of watertight ventilation zones which permit the use of modular HVAC and chilled water equipment. This is a decidedly more complex effort, but one which promises to have a significant impact on the way ships are designed in the future.

In addition to the RODM and Zonal/Modular HVAC initiatives, the ATC team is also investigating modular,

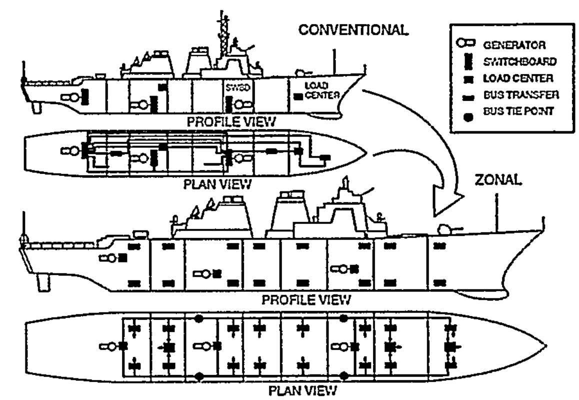


Figure 7. The Zonal Electrical Distribution System

common-family equipment for steering gear systems and an alternative firemain concept known as the single main/zonal firemain architecture system. The first three efforts are discussed in greater detail below; the single main/zonal firemain architecture has been previously reported upon by the ATC team (7).

Reverse Osmosis Module Development

The Navy's newly developed and qualified 12,000 gallon per day reverse osmosis (RO) plant consists of four major pieces — membrane, pump and filter skids, and a control/gauge panel — which require the usual foundations and interconnections when installed aboard ship. The team's original intent was to mount these items in a well-considered arrangement on a single base. Fabricated and interconnected in the shop, this module could be landed in the ship as one unit, making the necessary seawater, freshwater, and electrical connections onboard.

Though still the basic approach to RODM development, discussions with the NAVSEA technical codes responsible for shipboard distillation (SEA 03X23 and SEA 03Y32) have indicated that the value of the RODM would be enhanced by the addition of several items. Since all ships do not strain seawater service to the same degree, a strainer of the required gauge for this RO plant will be added. The Navy's new electrolytic disinfectant generator (chlorinator) will be included in the module, since this is a logical part of a potable water plant. Because single-pass RO water is not pure enough for electronic cooling, gas turbine water wash or boiler make-up feed, the team is considering the addition of a small, second-pass unit for these special needs. Shock and vibration mounting options are also being reviewed.

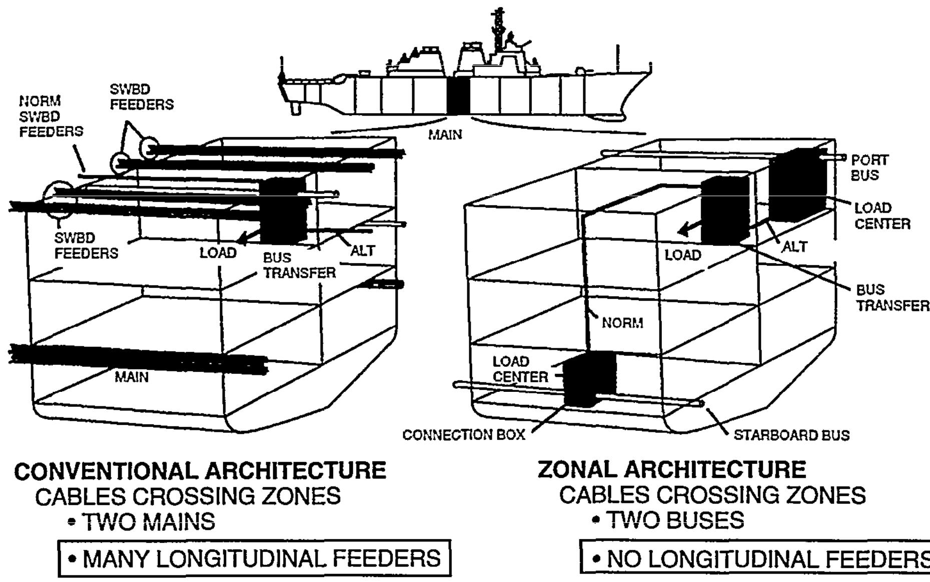


Figure 8. ZEDS Enhances Ship Producibility

The status of the RODM effort at the end of FY 93 includes development of an operability and maintainability test plan, and the completion of conceptual (Level I) arrangement drawings. The intent is to begin prototype module fabrication in late FY 94 using the Navy's prototype RO plant that recently completed shock and vibration testing, as well as the prototype chlorinator unit. An early conceptual drawing of the RODM is shown in Figure 9.

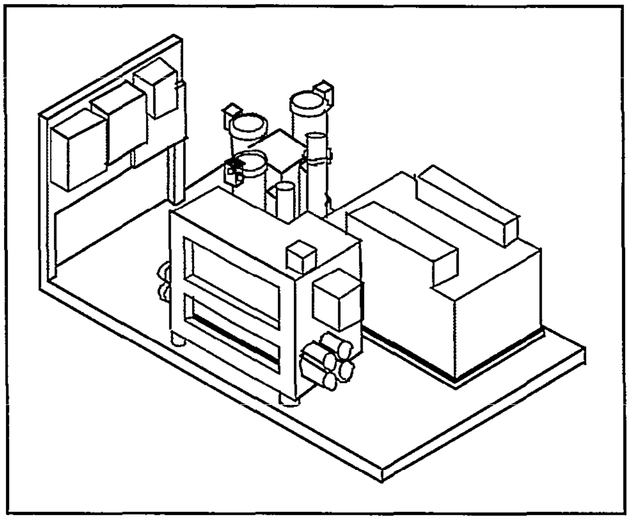


Figure 9. The Reverse Osmosis Desalinator Module

Zonal/Modular HVAC System Architecture

The primary performance attribute of the zonal HVAC system is to improve ship survivability by enhancing zone autonomy through strict vertical arrangement of the HVAC system on the ship's centerline. Accordingly, the ship is subdivided into watertight ventilation zones with separate, self-contained ventilation systems. The transverse bulkheads extending into the superstructure are smoke and fume-tight. Such a zonal architecture offers significant survivability advantages, as well as preventing the spread of smoke.

While the survivability aspects of a zonal HVAC architecture are quite attractive, the real incentive behind this study is the widely held belief that the current method of designing and building HVAC fan rooms and distribution systems is inefficient and expensive, and that the use of standard size modules to serve the needs of a simpler, more survivable zone is the most promising HVAC affordability option. To exploit economies of volume, ATC intends to develop common HVAC modules for fleetwide application in order to reduce HVAC design, construction, operating, and infrastructure costs overall (Figure 10). In addition to the HVAC system, ATC is examining various other distributive system architectures to dovetail with generic build strategies and other ship producibility efforts.

Because there are usually significant variations in

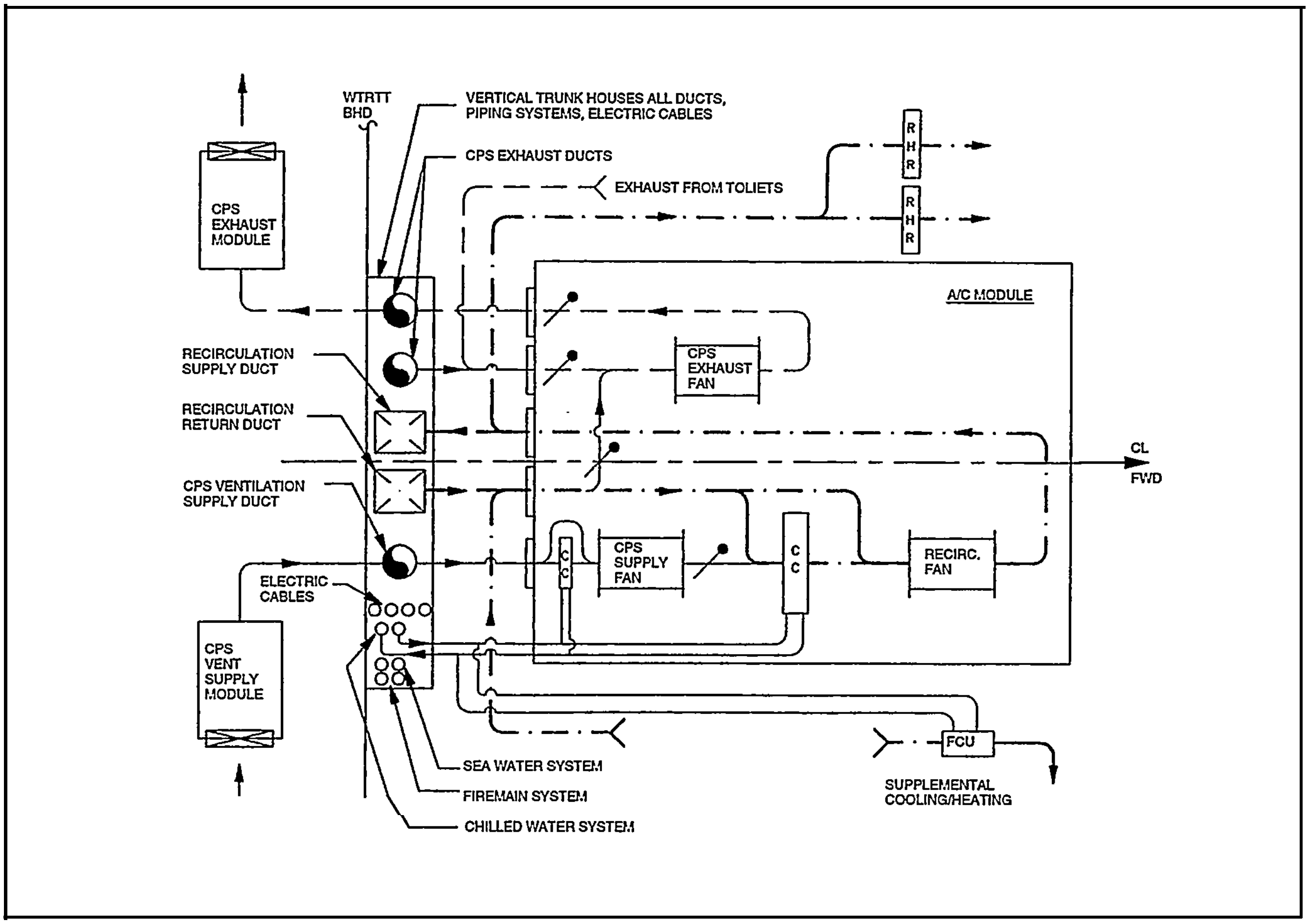


Figure 10. Functional Arrangement for HVAC Zonal/Modular Concept

HVAC requirements among the zones in any ship, it is difilcult to establish a "best fit" size for identical modules that can be used in multiples to meet the required load, particularly if it is intended to be used for an existing ship design. The step function aspect of module sizing can result in some zones which are over or under supplied, while other zones are right on the mark. Solving this problem is a matter of developing the connect common denominator module sizes, *and* designing anew ship such that the zones themselves are sized to take advantage of modular equipment. In addition, it is important to note that changes to existing HVAC requirements and design criteria may be required should development of Zonal/Modular HVAC architecture prove advantageous in naval ships.

The issue of HVAC design practices and requirements has been one focus of ATC team efforts in FY 93. Through consultation with the NAVSEA HVAC technical code (SEA 03V21), design criteria considered sacrosanct, those that could be changed to facilitate development of zonal architecture, and those considered relatively unimportant or unnecessary in a zonal configuration have been identified. The ATC team is currently working to develop workable updates to design criteria that would be violated by a Zonal/Modular HVAC system. A sampling of these issues is:

. Vital space independent of twin separate recirculation systems,
. Collective Protection System (CPS) design philosophy,
. Damage control classification (W,X,Y,Z) for zonal architecture,
. Airlocks between zones,
. Weather openings for zones that do not service superstructure, and
. Combat system (or AEGIS) cooling system failure analysis.

Development of zonal HVAC distributive systems, modular fan rooms, weather terminals, and chilled water plants will proceed in FY 94 as their respective design criteria issues are resolved.

Steering Gear

In the ATC team, the initial impression was that commonality of steering gear generally existed throughout the fleet. Closer inspection revealed that although the predominant number of systems were of the Rapson slide actuator type, size consistency between ship classes did not exist. Furthermore, it has been determined that there are technically acceptable alternative concepts which offer a more cost effective configuration. These include double-acting, single-ended cylinders and hydraulic power units employing vane-type double pumps. This concept is particularly appropriate for amphibious assault and auxiliary ships.

With respect to combatant ships, it appears that the Rapson slide and variable swash plate-type hydraulic pumps in a standard design with a family of sizes would be the most appropriate steering gear system. This equipment would also facilitate the incorporation of rudder roll stabilization in future ships.

With the knowledge this limited study provided, the ATC team intends to consider developing families of steering gear modules that have fleetwide application.

Standard Monitoring and Control System

Like the machinery systems themselves, machinery plant monitoring and control systems have traditionally been custom-designed for each class of ship. Little effort has been made to use common hardware or sofhvare within a given ship type or across ship classes. In turn, in-service engineering and logistics support capability have been developed and maintained for each of these unique control systems. Consequently, developing and supporting Navy machineV monitoring and control systems has proven to be very expensive.

The SMCS is a program element of ASMP which can significantly reduce the costs of developing and supporting monitoring and control systems for shipboard machinery systems. The use of only four unique enclosures can meet all hardware requirements for an integrated monitoring and control system (Figure 11). SMCS also provides an improved information architecture which ensures accurate and reliable transfer of information between modules and control stations in a machinery system. SMCS differs from current proprietary shipboard control systems by incorporating open standards and an open architecture. By avoiding proprietary systems, SMCS can enable multiple vendors to supply compatible hardware and software without contractual complications. SMCS also supports a software repository from which software modules can be selected to complete a control system package. In this manner, the amount of configuration specfic software (and attendant cost) is kept to a minimum.

The SMCS consists of core hardware and software for developing machinery monitoring and control systems for

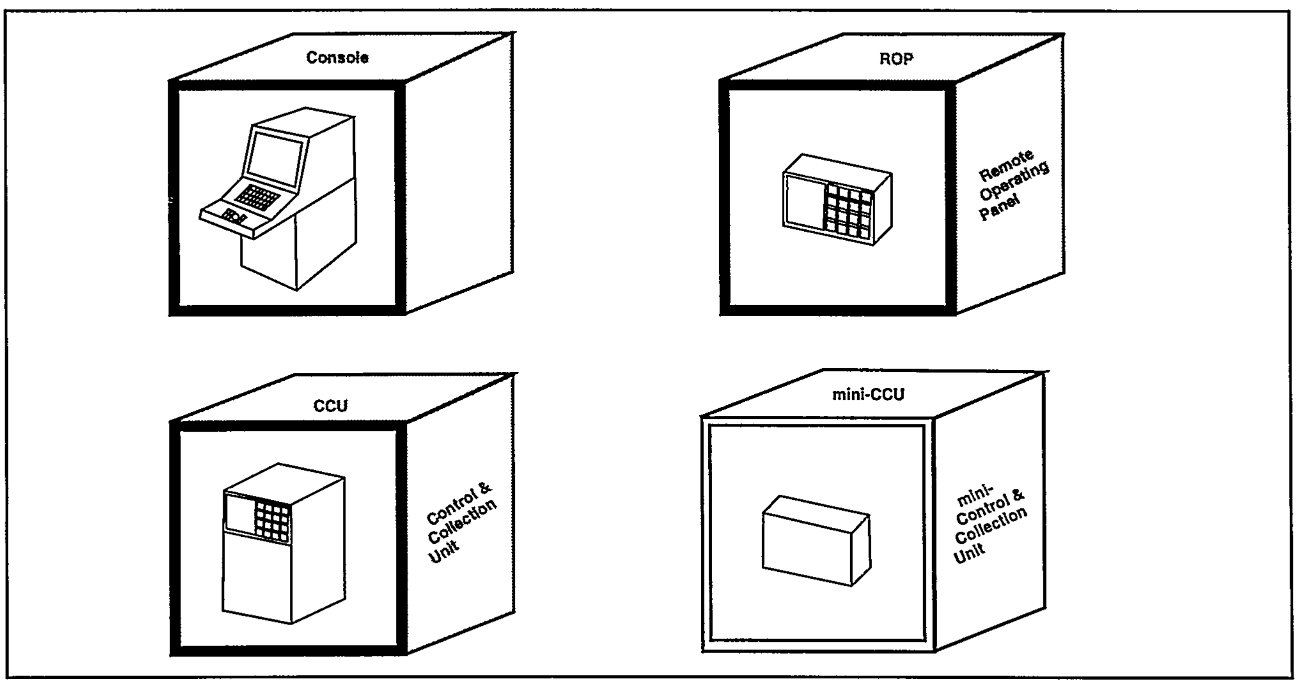


Figure 11. SMCS Hardware Building Blocks

backfit, forward fit, and new construction ships. SMCS hardware consists of standardized consoles as well as Control and Collection Units (CCUS) and Mini-Control and Collection Units (mini-CCUs). The consoles and CCUS are interconnected by a fault tolerant data communication standard, such as SAFENET II. Mini-CCUs communicate with CCUS via a local data communications standard such as MIL-STD-1552. The CCUS and mini-CCUS interface directly with machinery plant equipment comprising the propulsion, electrical, auxiliary and damage control systems (Figure 12).

The SMCS core software repository provides a collection of reusable modules from which a variety of monitoring and control systems can be easily developed. SMCS is intended to support the following systems:

- Mechanical drive propulsion plants (Gas turbine or diesel),
- Integrated Power Systems,
- Zonal Electrical Distribution Systems (Zonal AC and Zonal DC),
- Integrated Survivability Management Systems (ISMS),
- Zonal auxiliary systems,
- Condition Based Maintenance, and
- Onboard training.

Combat Systems

In the area of Combat Systems modules, ATC is building on earlier progress in modularity and standardization. VLS missile modules and AEGIS electronic modules have proven to save time and cost of installation; testing of completed modules can be accomplished offship and installation can be deferred until the zone in which the equipment is to be installed is ready to accept it. In addition, upgrades and modifications (e.g., missile load out mix) are easily accomplished.

One of the key objectives of ATC is to shift assembly and test to shop and on-block locations. For combat systems equipment this is particularly applicable to the assembly of guns. Currently, guns are built into the ship during initial construction. This includes machining the roller path in the deck and in situ assembly of gun components (e.g., train and elevation assemblies, ammunition hoists, ready service room equipment etc). Significant cost savings in this process are possible if the gun can be

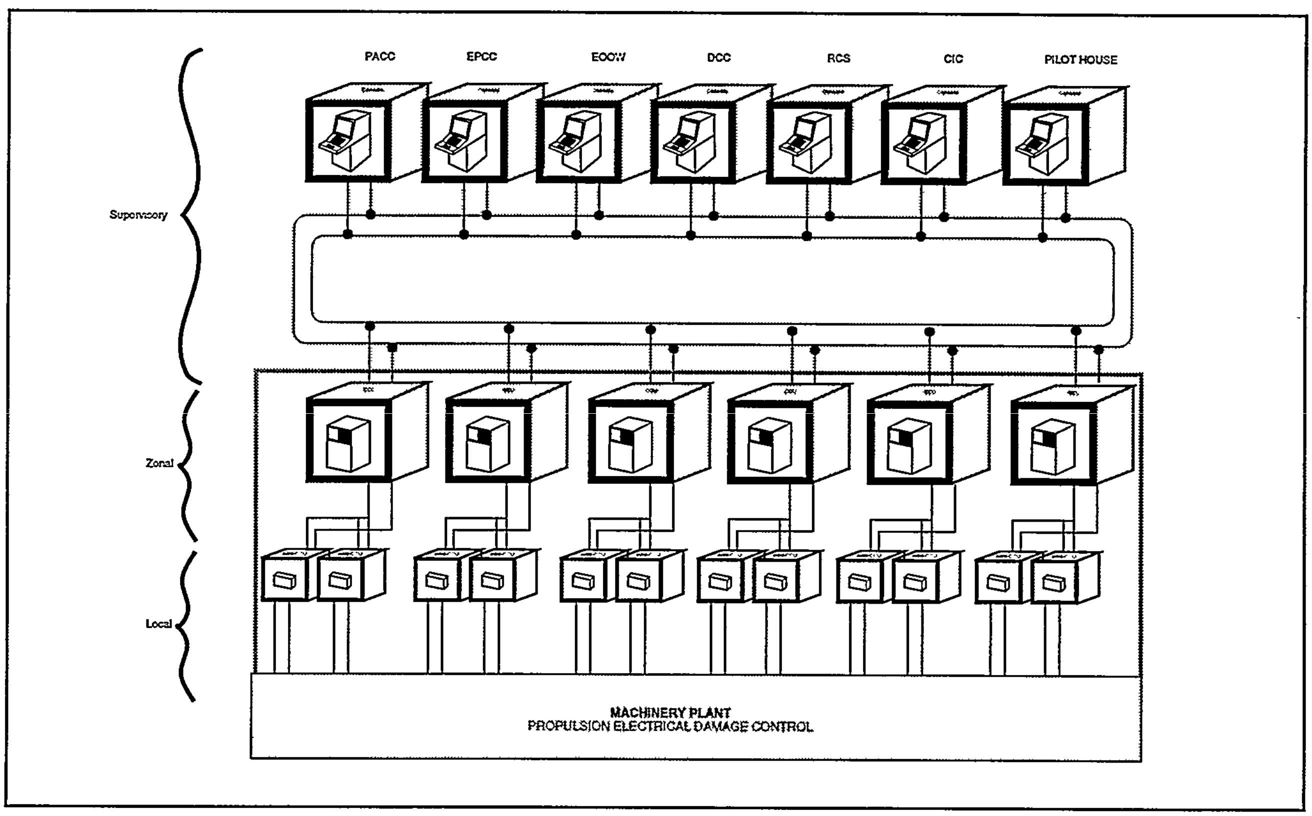


Figure 12. The Standard Monitoring and Control System

packaged as a module. This has been demonstrated in foreign built ships such as the Blohm and Voss MEKO modular frigates. Nearly 60 of these frigates have been built over the last ten years; several of these contain a 127mm (5 inch) modular gun.

To capitalize on this experience, ATC is proposing a foreign comparative test program for a modular 5"/54 caliber gun system (MGS), based upon the MEKO system. The MGS will consist of the 5"/54 caliber gun assembled in an installation module. The MK 45 5"/54 caliber gun is standard in the U.S. Navy and will remain so beyond this decade. AA-size module installations, which provide the gun mount structural support, are fully outfitted with gun ancillary equipment and provide all gun/ship system interconnections. The modular concept allows gun system pre-outfitting and intra-system testing prior to ship installation in a protected environment. This, in turn, reduces shipboard outfitting and checkout time, promotes installation standardization, and facilitates in-service gun system replacement time. This approach also eliminates the time consuming process of machining the gun mount and ship interface onboard ship, and simplifies the on-board alignment of the pre-machined loader mechanism. The MGS provides near term results for the ATC program in that it has widespread application throughout the fleet. The MGS is shown in Figure 13.

In addition to modular ordnance systems, ATC will review current and future combat system functional elements with the approach that increased modularization and interface standardization will facilitate improvements in offship testing and ship installation, as well as ease of upgrade and contracting control. This effort will determine the functional groupings of respective equipment. Some of the criteria to be used in this determination include:

- Mission association and/or relevance,
- Manufacturer commonality,
- Production and/or integration testing,
- Maintenance access,
- Equipment size and/or weight,
- Service needs,
- Structural and/or subdivision boundaries,
- Secondary removal and/or replacement,
- Ship access and/or zone location,
- Cabling termination, and
- Installation procedures.

To assist in development of the above criteria, dockside and shipboard testing will be examined in detail. Using ATC modularity and interface standards, existing procedures for Total Ship Test Program Stages 2, 3, and 4 might be greatly simplified through offship testing.

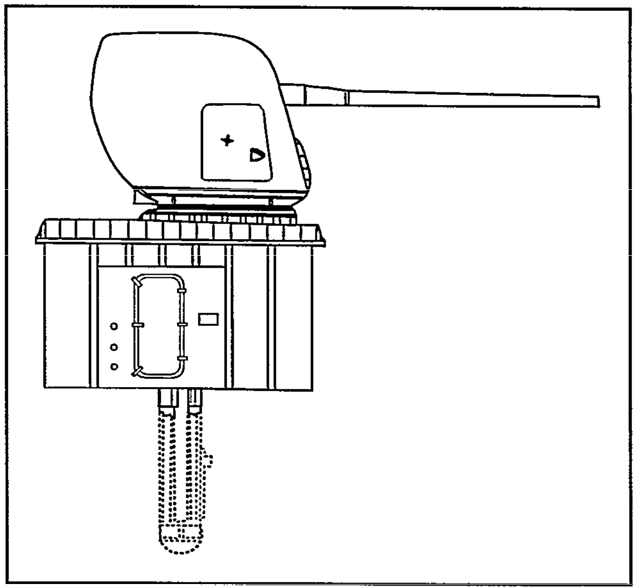


Figure 13. The 5"/54 caliber Modular Gun System

For example:

Stage 2 - Installation, Inspection and Tests. These tests demonstrate that integrity, strength, and continuity are applied to foundations, cabling, sonar domes, piping, ventilation, air conditioning, switchboard, interface connections, etc. in accordance with module/module station installation requirements.

Stage 3 - Equipment/Equipment Group Assembly Tests. These tests demonstrate that individual or groups of equipments perform within specified tolerances. Included are safety checks conducted prior to equipment operation, as well as initial light-off tests.

Stage 4 - Intersystem/Integrated Combat System Tests. These tests demonstrate that two or more independent but interfacing combat system elements perform within specified operating and alignment tolerances. This includes the exchange of intersystem signals, commands, functions, and associated software interfaces.

Installation and Integration

The correct choice of systems architecture can reduce ship construction costs by enabling improvements in construction efficiency. The modern concept of shipbuilding is to construct and outfit large ship assemblies (zones) which are then welded together to form the ship. System architectures can maximize the benefits of such a construction process by minimizing and simplifying the system interfaces across ship assembly zone boundaries. Unfortunately, current ship designs do not fully support

this process. An example is that propulsion shafts require careful alignment through multiple zones, while conventional electrical distribution and other distributive auxiliary systems require hundreds of pipes, ducts, and power cables to cross ship construction boundaries.

The ATC/ASMP approach is specifically intended to facilitate the zonal ship construction process. The IPS removes the requirement for long shaft lines. Zonal electrical distribution reduces the number of cables crossing construction boundaries. The SMCS reduces the total amount of machinery system control wiring. The use of machinery and combat system modules allows maximum assembly, outfit and pre-testing concurrent with the earliest stages of the ship construction process.

Fully outfitted and pre-tested, these modules are transported to the construction site for integration into ship assemblies. When construction and outfitting of a ship assembly zone is completed, the equipment and systems within the zone can be tested as an independent section of the ship. (Module tests which duplicate factory tests are not required.) When zonal tests are completed, the assemblies are joined to form the ship. The necessary final ship systems tests are then accomplished. In general, tests accomplished in the earliest possible phase of the ship construction process enable monitoring, troubleshooting and repairs in the least costly manner.

Successful integration of these modular assemblies will require strict discipline by the shipyard to check, reassemble as required, align and connect support services if problems are to be avoided. Receipt and inspection criteria includes such elements as: visual inspection, standard equipment lists (for module components), packing, handling, storage, transportation, test, Quality Assurance (QA) and Integrated Logistics Support (ILS) documentation. Experience by shipyards who have been utilizing modularity for nearly twenty years indicates that such an approach facilitates control of vendor equipment. In fact, there was a marked improvement in quality and a minimum adverse impact when these responsibilities were established. This eliminated confusion and overlap of efforts.

Even with an increase in the number of modules provided to the shipyard, the yard will have to assemble several of these together into a larger unit. At this point, assembly criteria will have to be established which will include structural methods, service interface placement, service interface connection assembly, construction tolerances, weight and dimensions limits, materials, and workmanship. For example, for many modules and subassemblies, alignment will be critical. Such issues as environmental considerations, perpendicular and/or parallel structure criteria, bolt hole alignment and foundation flatness requirements must be addressed. To assist in easy alignment of foundations, it is expected that special tools and jigs and/or drill fixtures will be used extensively (Figure 14).

Some of the shipyard functions associated with module integration and installation will include preinstallation interface checkouts. This will require criteria for interface checkout of tools and instruments, standard connectors and parts, working access and clearances, piping, cable, duct sizes, and quality. Such interfaces will also be controlled onboard ship, either as part of on-block outfitting or final construction. Successful implementation of this process will depend on the ability to validate module fluid, electrical, HVAC, and control system interface requirements (Figure 15).

Handling criteria may have to be developed for some types of modules, as there maybe some unique requirements associated with the equipment in these modules. Handling criteria would include lift weight data and safety factors, access and egress planning, acceptable deflection and stress limits, and overall safety measures. For heavier modules, such details as lifting methods, chainfalls, sling designs, braces and strongbacks maybe designated.

The need for dialogue with shipyards during the development of the ATC/ASMP approach to installation and integration cannot be overemphasized. If the production process is to be streamlined, the use of common modules can play a key role.

Costing

Material, whether contractor-furnished or Govemment-fumished, represents over 60 percent of the cost of any naval ship. Using standardization and large volume procurement, the cost of this material can be reduced by 30 percent. In light of previous experience with the DD-963 class destroyers, this estimate is very realistic. Such a reduction would result in an 1 S percent reduction in overall ship unit cost.

Increased productivity due to use of modular subassemblies has been shown to reduce overall ship construction costs by 10 percent. In addition, by shortening the detail design and construction cycle from 49 months to 36 months, overhead (management and facilities) costs of ship construction could be lowered by 5 percent. Thus, full implementation of the ATC policy could yield a reduction in ship acquisition cost of 33 percent, approaching the 40 percent actually achieved by the Japanese (2).

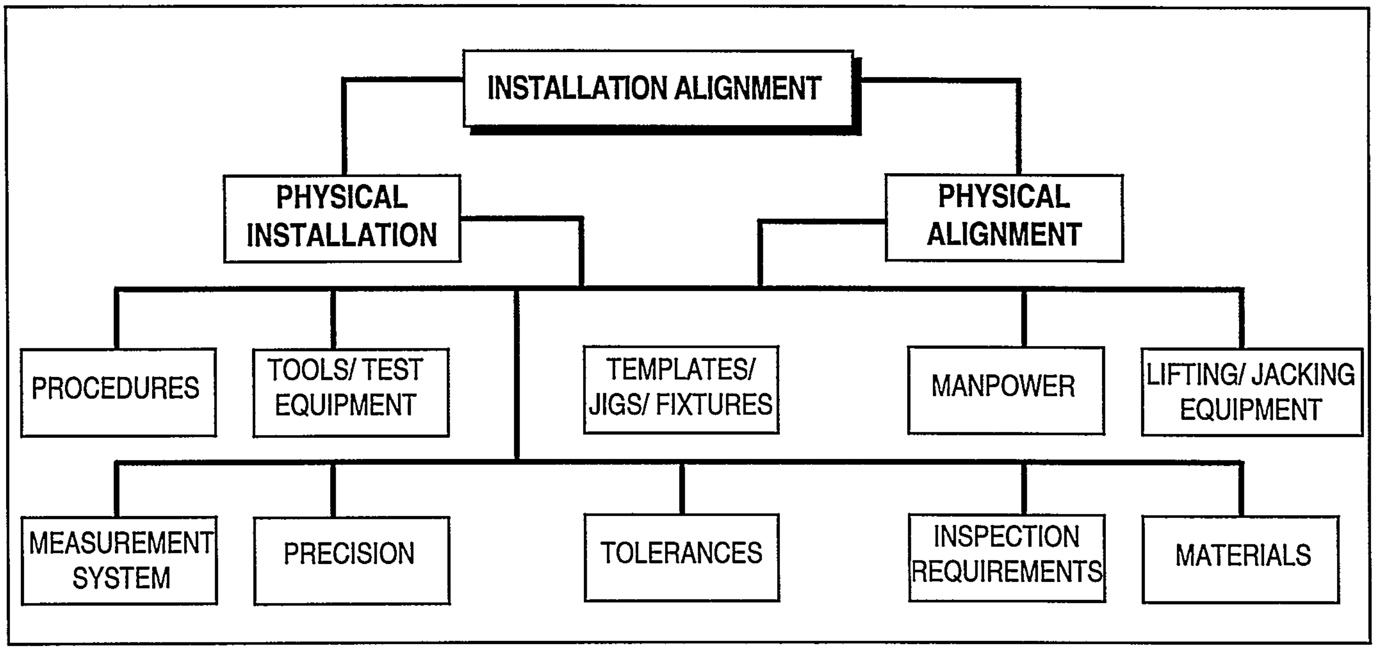


Figure 14. Installation Alignment Criteria

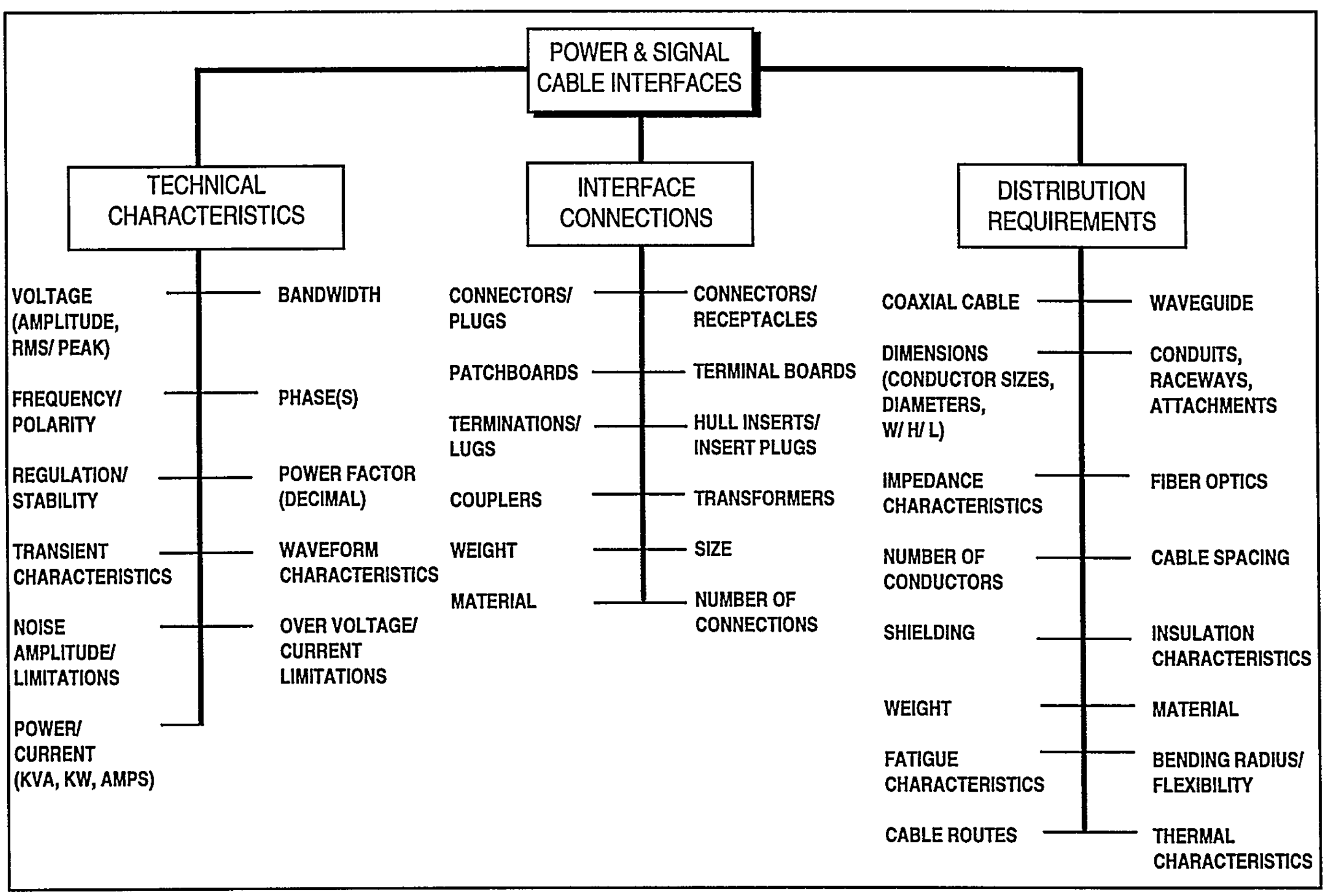


Figure 15. Power and Signal Interface Criteria

To further reduce production costs, military quality control oversight should be aligned to the maximum extent possible with comparable industrial standards, such as ISO-9000. Special fabrication processes should be used only where absolutely necessruy. Ideally, cost accounting and program management should allow use of the same methods and facilities for both commercial and military manufacturing projects. In this context, any factory test conducted to verify module integrity/operability should eliminate the need for the same testing at the ship construction site, prior to ship integration.

The Navy's acquisition strategy for a given type of equipment or class of ships will determine how common modules will be procured. They may be obtained from a government item manager as Government Furnished Equipment (GFE) or constructed by a specialized integrator (including the building shipyard). As long as module specifications are followed, the most cost effective acquisition method should be chosen.

Ship design will be impacted by the ATC process in that it can start to proceed with a set of known building blocks which have been thoroughly reviewed by design, procurement, construction, life cycle management, and operational personnel. Such approaches to module development have been adopted by Martin Marietta with impressive reductions in costs. A design change which costs $100 to make in the product design phase would cost $100,000 for the comparable system modification to be accomplished in the field. With the ATC approach, these product design changes can be accomplished more rapidly. It is estimated that the overall ship design, procurement, and production cycle could be reduced from 111 months to 72 months - a reduction of 39 percent (Figure 16). Even allowing for multiple reviews during combined preliminary/contract design stages (including shipyard and module manufacturer representatives), the schedule still allows two years for the design of a Navy ship.

Future direction

The combined ATC/ASMP project is oriented towards providing commonality options to ongoing and future ship acquisition programs. These options must be offered early enough in the design and acquisition cycle to impact procurement decisions. In addition, there should be enough equipment production volume to realize measurable cost savings from early commonality-based products. This philosophy has led to an emphasis on providing commonality options for the LX amphibious assault ship and the DDG-51 guided missile destroyer, Flight DA. Upcoming years will see the continued development of commonality products and procedures selected for utilization by these programs, and the expansion into providing similar options for future ship designs. The general plan is to expand from the early ATC base in HM&E and weapons systems equipment into the broader field of combat systems and

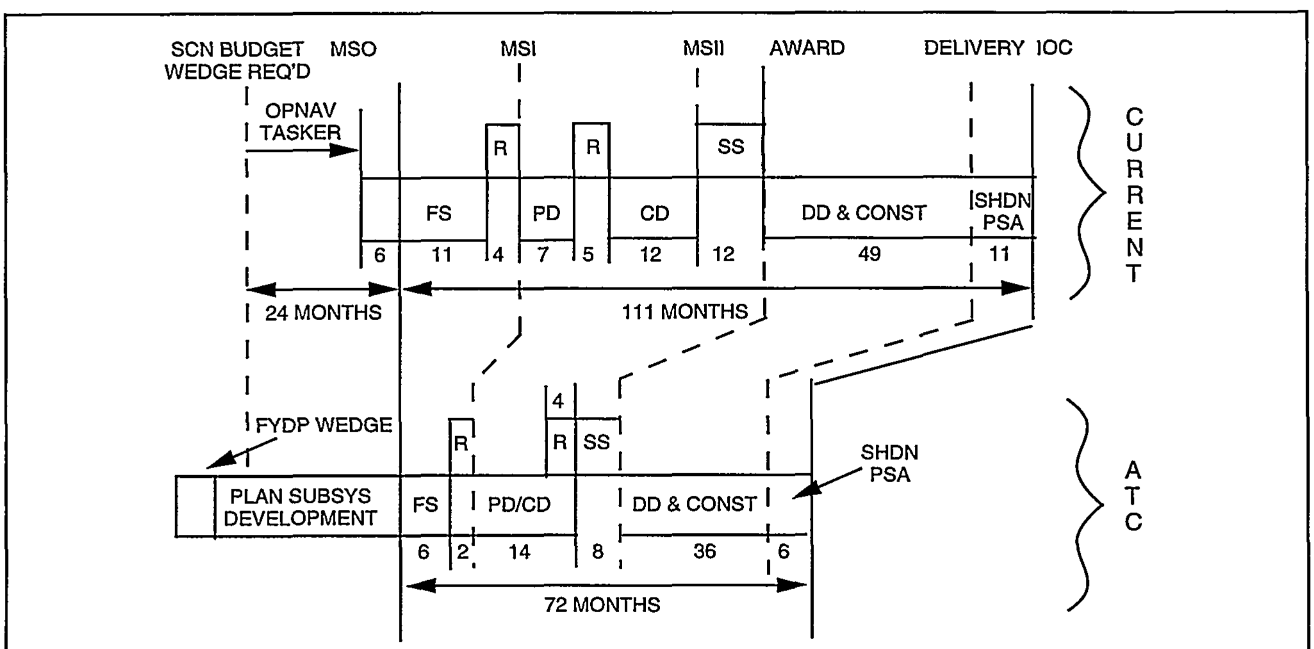


Figure 16. Comparison of Current versus ATC Design and Construction Milestones

communications. The goal is to map the feasibility and format of commonality for the *whole ship* and for *every ship,* over the course of a ten year project life. Providing full commonality-based options for ships contracted after the year 2000 and revised, affordable processes for NAVSEA to implement as the mainstream process for conducting naval ship design, acquisition, and in-service support is the ultimate goal of ATC. The extent and success of this implementation will be measured by the degree of architectural impact on such post-2000 ships as SC-21 (future surface combatant) and LVX (Mure flight deck amphibious assault ship).

SUMMARY

The ATC project is in the first developmental year of a multi-year task. It is estimated that seven to ten years of steady effort and reliable funding are required to achieve a commonality-based design infrastructure that can dramatically benefit the affordability of the acquisition process and eventually the in-service support process. These benefits can be phased into each subsequent new ship design as various prototype modules, design and cost tools, generic build strategies, and databases are developed and accepted for use by the Navy ship design and acquisition community.

This effort is consistent with recent recommendations of the Defense Science Board in the areas of Integrated Product and Process Development (IPPD) and dual-use manufacturing (8). The process improvements of the Navy and the commercial maritime industry can and must dovetail to restore balance of performance, quality, and affordability to the design, construction, and operation of America's ships.

REFERENCES

1. "Modularity, Standardization and Simplicity - Three Keys to a More Affordable Navy:' by RADM M. S. Firebaugh and CAPT Robert Percival, presented before the 1992 Ship Production Symposium in New Orleans, 2 September 1992.

2. "Naval Ship Affordability: Assessment of Increased HM&E Commonality Across Ship Types," NAVSEA Report 070-05R-TN-O04, May 1993.

3. "Improvements in Ship Affordability," by CDR Michael Bosworth and Jeffrey Hough, presented before the SNAME Centennial Meeting in New York, September 1993.

4. "Integrated Power Systems for Amphibious and Auxiliary Ships," by LT Norbert H. Doerry, USN, Advanced Surface Machinery Programs Office, Naval Sea Systems Command (NAVSEA 05Z), 23 June 1992.

5. "Zonal Electrical Distribution Systems: An Affordable Architecture for the Future," by Chester R. Petry and Jay W. Rumburg, Naval Engineer's Journal, May 1993.

6. "A Strategic Plan for the Affordability Through Commonality Project," prepared for CDR. Michael Bosworth (NAVSEA 05R3) by Decisions & Designs, Inc., December 1992.

7. "Development of a Zonal Architecture Fire Main System for Combatant Ships," by Mark E. Shiffler, Naval Entineer's Journal, May 1993.

8. Engineering in the Manufacturing Process, Defense Science Board Task Force Report issued by the Office of the Under Secretary of Defense for Acquisition, March 1993.

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